OBSERVATIONS ON LIVING SOLENOMYA
(VELUM AND BOREALIS).

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The genus *Solenomya*, represented by a few species, is widely distributed throughout the world. It has been found on the east and west coast of North America, in West Africa, the Mediterranean, the Canaries, Australia and New Zealand. The few species agree in almost every detail but vary greatly in size. Our two species, *S. velum* and *S. borealis*, are one inch and three inches long respectively. *S. bartschi* from Manila is eight and one half inches in length. The species vary greatly in the proportional number of individuals. *S. velum* is at times thrown up by thousands on our beaches, *S. borealis* is rarely found. *S. grandis*, which departs more widely from the type than the others, is known by two specimens and a few fragments, while the gigantic *S. bartschi* is represented by a single specimen. The various species have without exception a long semi-cylindrical shell, rounded at both ends, a long and almost straight hinge margin. They all have radiating ribs with an apparent inter-space in the series in which however a faint rib may be detected. They all have a highly polished periosteum which runs far beyond the border of the true limy shell, and to which the mantle with its curious system of muscles is closely adherent. The radiating ribs are continued through the overlapping periosteum by a marked thinning of the substance and Professor Drew discovered that when the periosteum folds inward as the valves close these thin areas fold in a plaited manner. In the dry state these interspaces often split and the substance being very brittle it is hard to preserve unbroken in cabinet specimens. The various species vary from a light yellowish brown to a dark brown and even a tar color. The shell within is grayish blue or lead color in *S. borealis*, purplish white in *S. velum*.

Pelseneer[8] has shown that *Solenomya* has a very primitive form of gill and Mitsukuri[7] had previously studied the gill of

Nucula and *Yoldia* and showed also the primitive condition of the gills in these genera. Pelseneer has united *Solenomya*, *Nucula*, *Leda* and *Yoldia* in an order under the name of Protobranchia, forming the lowest order in Lamellibranchs. It is interesting to observe that, while other genera of this low order vary greatly among themselves and from each other, *Solenomya* remains fixed in character despite the wide variation in size among the species and their wide distribution in space.

With the exception of the incomparable work of Deshayes,[2] that of Stempell[11] and Pelseneer[8] on *Solenomya togata* and that of Drew[3] on *Solenomya velum* there have been very few observations on the anatomy or habits of the living creature, and most of the records are derived from accounts of previous observers, and these were in many cases incorrect. Gould says the foot of the animal protrudes behind, whereas it protrudes in front; that the edge of the mantle opening is fringed and that two of the fibrils are larger than the others, which is incorrect, as regards our species and that the palpi are triangular, whereas they are long, narrow and semi-tubular. Stimpson's description, though brief, is without error. Professor George N. Perkins,[9] in his "Molluscan Fauna of New Haven," a memoir teeming with details concerning the soft parts of Mollusca and their habits, has given one of the best accounts of *Solenomya* ever published in this country. Carpenter, in his lectures on Mollusca, says the mantle is closed in front, whereas it is wide open, and that there is a tail on each side of the external opening. Cooke mentions the two long tentacles springing from the siphonal orifice. Stempell figures in *S. togata* two papillæ much longer than the other siphonal processes.

There is a puzzling discrepancy in the figures of the siphonal tentacles of *Solenomya togata* as portrayed by various authors. Philippi[10] figures *S. togata* with short siphonal papillæ resembling a rosette. Pelseneer,[8] in his contributions to the study of Lamellibranchs, figures this species without a trace of long siphonal tentacles. In his introduction to the "Study of Mollusca" he gives a figure of *S. togata* with a pair of siphonal tentacles 17 mm. long. This figure is however copied from Deshayes'[2] "Natural History of Mollusca." It is probably

from this figure that Carpenter, Cooke and others have derived the long tail or tentacle mentioned by them. The excessive length of the two tentacles figured by Deshayes suggests the curious retractile tentacle in *Yoldia limatula* as described by Brooks.[1] A careful examination of *S. velum* however showed no trace of such a sense organ. Stempell,[11] who studied this species at Dohrn's laboratory and published an account in 1899, figures two siphonal tentacles 3 mm. in length. Are these differences the result of variation? Is there more than one species of *Solenomya* in the Mediterranean? Have the drawings been made from alcoholic specimens? The mystery can only be cleared up by a study of the living creature.

In the following observations of *Solenomya velum* I have been greatly indebted to Mr. William F. Clapp, of Cambridge, and Miss Marjorie Newell, of Gloucester, for the material herein described. Mr. Clapp brought me thirty-nine living specimens of *S. velum*, young and nearly full grown. These were collected April 27, on Round Flat, a sandy mud area in Duxbury Bay. They were all buried from six to nine inches below the surface. Mr. Clapp believed they were simply inhabiting abandoned worm holes. Although powerful diggers he thinks they ordinarily dig but an inch or two deep. If they do dig to the depth he found them he believes they must occupy the same burrow for a considerable length of time, for in every case he observed the sides of the hole were discolored, closely resembling worm holes. I placed three specimens in a jar of sandy mud and they soon burrowed to the bottom of the vessel, leaving three sharply defined round holes on the surface of the mud. Drew says: "*Solenomya* lives in rather hard mud, frequently very sandy mud, and, I think, keeps its burrow more or less open." The holes which Mr. Clapp observed and which he cautiously suggested might be abandoned worm holes were undoubtedly holes made by *Solenomya*. Verrill says in regard to *S. velum* that it is "occasionally found burrowing in the pure fine silicious sand near low-water mark, about two inches below the surface, but its proper home is in shallow water beyond low-water mark, and it is perhaps most abundant when there is mud mixed with sand and it also lives in soft mud."

The manner of burrowing is peculiar. In one case an individual buried itself siphon end downward, and for three days remained in this position with its disk-like foot level with the surface of the mud. In every case the individual rested on the bottom of the dish, ventral region uppermost and valves widely open, limited only by the closed portion of the mantle which is drawn tense by the distended valves. When placed on the surface of sand or mud it soon pushes itself backward by means of its foot which, assuming a pointed tongue-like shape, is thrust forward and downward lifting the anterior end and thus depressing the posterior end. Others buried themselves and went to the bottom of the dish, where they remained in a horizontal position. Whether they went head first or tail first was not observed. Others buried themselves in the mud and remained out of sight for hours with no burrows communicating with the surface. Drew states that *Nucula delphinodonta* buries itself in the mud with no surface communication. The strong alternate movements of the sides of the siphonal area may be related to the habit of burying itself posterior end downward. As a further proof that *Solenomya* buries itself siphon end downward may be cited the condition of a young *Solenomya borealis* preserved in alcohol for dissection. I found adhering to the anterior end of the shell close to the margin three colonies of a species of sponge. Here was an evidence that the creature had not only been buried siphon end downward, but that the anterior end had been slightly protruded above the level of the sand and had remained in that position long enough for the accumulation of foreign growth. The periosteum is so exceedingly smooth and polished, and the creature is so active in its swimming habits that the adhesion of foreign growth would hardly be looked for.[1] An examination of a number of shells showed little evidence of wear or burial at either end. The pedal opening is so large and the activities of the foot are so incessant that more water is admitted anteriorly than posteriorly and the siphonal opening has little to do so far as conveying water and food to the gill cavity is concerned.

[1] Dr. Drew informs me that in digging this species from the mud many of them float on the surface of the water, the periosteum repelling the water as if oiled.

If burrowing posterior end downward is a common habit of *Solenomya* it forms an exception to all lamellibranchs that burrow. So far as I know all lamellibranchs that burrow in sand, mud, wood or stone penetrate the substance anterior end first, and in that position they rest. Indeed the foot is the primary instrument used in effecting this penetration. *Solenomya* is unique in this respect.

As before stated the creature, resting on its back, thrusts out its foot in a pointed shape, presses the bottom of the dish, then immediately withdrawing it at the same time expands the fimbriated disk which unfolds in a graceful manner, and in that expanded condition swings back and forth a few times in the pedal opening which is widely distended. The overlapping periosteum then folds abruptly within the shell, which closes at the same time as the thick foot is drawn in between the polished walls of the periosteum. The creature then falls over on its side and remains in that position until the valves again open which is almost immediately. The method of swimming has been accurately described by Drew. The act consists in thrusting out the foot, promptly expanding it and then suddenly withdrawing it, at the same time closing the shell and expelling the water from the siphonal end. These motions are often repeated a number of times without the animal moving at all. When these movements are made with sufficient vigor, however, the animal seems to leap or dart in the water, anterior end forward, going three or four times the length of the shell at each leap.

Stimpson says: "The thinness of the shell enables the animal to make surprising leaps and I have seen it leaping or swimming about the water for some time without touching the bottom. The leap is performed by suddenly drawing in the umbrella-shaped foot, at the same time that water is expelled from the posterior opening by the closing of the valves." I counted the number of darts made by different individuals and, though the specimens I had were probably enfeebled by their long transportation in a small glass vessel, I found the following result—22, 24, 31 and 36 darts respectively were made before the creature fell to the bottom of the dish. The 36 darts were made by a young individual. The darts were vigorous, and were made at the rate of 90 to 100 a minute.

The violent activity of the animal in its rapid darting through the water, the repeated thrusting out of the heavy pedunculate foot and vigorous closing of the valves accounts for the necessity of the continued absorption of food as indicated by the rapid accumulation of flocculent fœcal matter in the dish.

The thirty-nine specimens, young and nearly adult, collected April 27, were placed in a white enamelled pan and showed no signs of increased enfeeblement for a week or more. The water was changed often. At the end of three weeks they were all dead, the young ones surviving the longest.

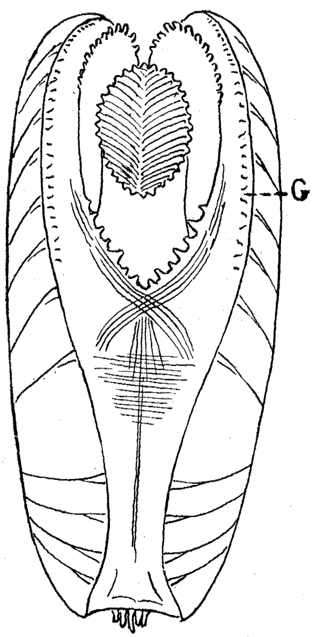

FIG. 1. View of animal from below.

The individuals showed no sensitiveness to the obstruction of light, nor did they align themselves in any special way in relation to the lighted window. They did not seem to have the sensitiveness of other lamellibranchs; the jarring of the table did not cause them to close, though agitating the water or touching them with a needle ever so slightly prompted them to close their shells, which remained closed for a few seconds, when they slowly opened and repeatedly thrust out the foot. In fact they became very lively after agitating the water.

As one views a specimen from below with the valves wide open and the closed part of the mantle stretched like a drumhead from the margin of the periosteum, the calcified portion of the shell is hardly in view. The periosteum, extended as it is when the valves are open, shows no marked shoulder or channel at its junction with the thin membranous mantle, though in section a slight break is seen. The pedal opening is wide and extends backward nearly to the center of the body, where the free mantle edges come together, forming an elongated oval opening when distended, and through this opening

the thick stocky foot is seen occupying the whole space (Fig. 1). At the point of junction of the two sides of the pedal opening there are crowded together muscle fibers, producing a silvery appearance, and at this point muscle fibers that run parallel to the borders of the pedal opening—which Drew described as in the nature of sphincter muscles—cross to opposite sides and continue their course posteriorly. May not the origin of the peculiar sharply defined cruciform muscles in *Solecurtus*, *Tagelus*, *Macoma* and *Tellina* be traced to these separate crossing muscle fibers in some primitive lamellibranch like *Solenomya?*

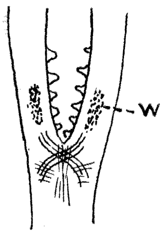

FIG. 2.

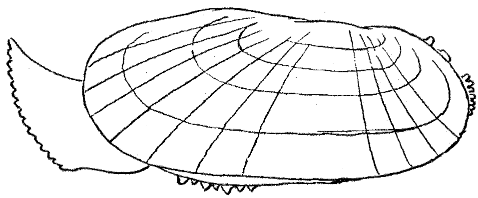

FIG. 3.

FIG. 4.

FIG. 2. Pedal opening showing white area, *W*.
FIG. 3. Side view of animal.
FIG. 4. Papillæ on margin of pedal opening.

The edge of the pedal opening is at times reflected and at its junction in the median line a few blunt papillæ or tubercles appear along the edges to nearly half the length of the opening. These are so aligned that when the two edges come together in closing the tubercles interlock. In Fig. 2 the tubercles are seen with the pedal opening nearly closed. They vary in size, are contractile and stand out at a sharp angle from the border so that they are distinctly seen when the animal is viewed from the side (Fig. 3). Until nearly adult these tubercles are translucent, but in the oldest specimens they become opaque white, resembling white kid, and appear hard and horny until touched when they partly retract. They are covered with a transparent epithelium (Fig. 4). This peculiar whitening not only covers the tubercles but whitens the mantle border from which they spring. A blotch of white is also seen between the tubercles and the keen edge of the periosteum, which at this point is also

touched with white. Even the base of the foot behind has a small blotch of white showing only when the foot is greatly elongated. This coloration in all exposed parts of this region is certainly a curious feature. It is as sharply defined and localized as if one with a paint brush had delicately touched with white every exposed part of the animal within this limited area. It is true the external shell is also touched with white at the anterior end. In the young a dot of white is seen in the first three or four transparent interspaces of the free periosteum. In older specimens these white spots are drawn out in broken lines; not in all specimens, however. In older specimens anteriorly the

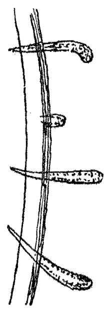

FIG. 5.

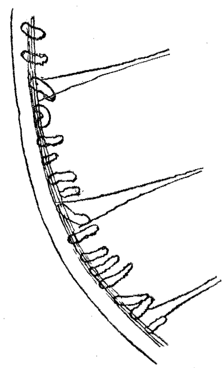

FIG. 6.

FIG. 5. Glands from side of pedal opening.
FIG. 6. Glands from anterior mantle margin.

whitening is sometimes seen on the dorsal side of each rib. This peculiar coloration is apparently correlated with the attitude of the animal in nature. Resting on its back the ventral region of the animal shows this whitening. Are the white markings at the anterior end of the shell another indication that the creature more often or habitually buries itself siphonal end downward?

Along the anterior half of the mantle, as it springs from the edge of the periosteum, are seen a number of what appear to be short white lines with glandular enlargements. They begin a little in advance of where the mantle parts, forming the pedal orifice, and are separated by a considerable space (Fig. 5), becoming crowded toward the rounded anterior border (Fig. 6). They spring from just under the edge of the periosteum and

point in the general direction of the median line, but are disposed irregularly in the membrane, some inclined forward and others backward, but most of them are at right angles to the mantle border (Fig. 1. G). Under a higher power these bodies have the appearance of setigerous follicles. Stempell figures one in his memoir of *S. togata* as a simple alveolar border gland. His figure shows a much more bulbous gland and the thread-like extension is not shown as in those here figured (Fig. 5). It was some time before I determined that there was no protuberance beyond the surface of the mantle, so strong was their resemblance to setigerous follicles.

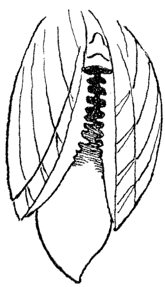

FIG. 7.

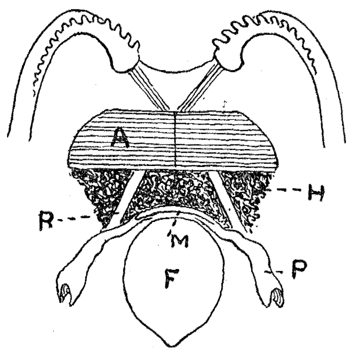

FIG. 8.

FIG. 7. Anterior view of animal.

FIG. 8. Anterior end from below: *A*, anterior adductor muscle; *F*, foot in section; *H*, hepatic follicles; *M*, mouth; *P*, palp-appendages; *R*, pedal retractors.

The margin of the mantle becomes thickened as it borders the anterior end of the shell and ends abruptly just before the shells meet dorsally. Just in front of where the shells meet above are two short unpaired tentacles or tubercles in the median line and then ten or more on the edge of the rounded anterior edge of the mantle on each side diminishing in size, however, toward the ventral region, where they cease (Fig. 7). Writers have described the whole free edge of the mantle as bearing these papillæ and even shown them in figures. Looking at this region from below the abrupt termination of the thickened mantle margin and the papillæ are shown (Fig. 8). A triangular muscular layer seems to connect the two thickened portions of the mantle dorsally. Also a narrow band of fibers runs from the

abrupt terminations of the mantle converging centrally. Fig. 8 shows the relation of these various parts in front of the anterior adductor.

As the animal becomes enfeebled the mantle (or, what would be a more proper name, the ventral membrane) ruptures, exposing the dark-colored gills below. There is a median suture in this ventral membrane and in one rupture the suture became dislocated, showing there was a strain upon it. In another case a small rupture appeared on each side of the median suture. That this membrane limits the expansion of the valves is shown by cutting the membrane, when the valves immediately open

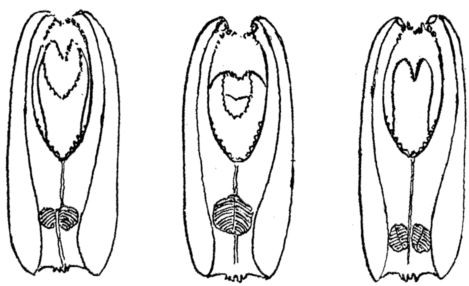

FIG. 9.

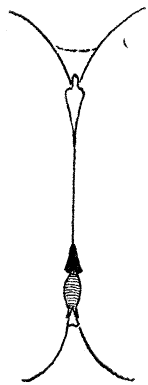

FIG. 10.

FIG. 9. Various attitudes of foot, and ruptures in ventral membrane.
FIG. 10. Dorsal view of hinge margin.

wider in much the same way as when the adductors are severed in other lamellibranchs. Fig. 9 represents the various ruptures, and at the same time illustrates different attitudes of the foot. In the adult the pedal opening extends back nearly half way to the center of the body. In the young it extends a little over a third back. Viewing the shell from above, the exposed ligament presents some curious features which I have tried to represent in Fig. 10. In the vicinity of the umbones a narrow elongated wedge-shaped substance, black in color, is seen, behind which a brown oval ligament appears, split at its posterior end in which is wedged a white substance. From the junction of the two valves anteriorly a narrow wedge-shaped substance narrowing posteriorly is peculiar in being a polished white. In the young

the periosteum is light yellowish, growing darker as age advances. The hypobranchial gland appears as a mass of globular cells containing short rod-like bodies. A number of graceful attitudes are shown in the movements of the pedal disk which I found difficult to figure. The fimbriated edge shows as distinct short tentacles with grooves running down outside, corresponding to the tentacles and corresponding lines or grooves in the disk running to the median line resembling a diminutive actinoid coral *Fungia*. At other times the edge of the disk appears serrated. These number thirty in all (Fig. 11). In the young these resemble long papillæ.

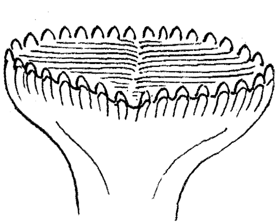

FIG. 11.

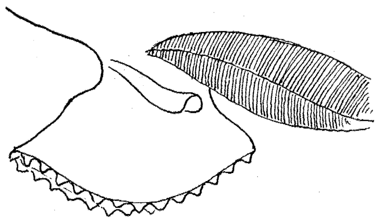

FIG. 12.

FIG. 11. Dorsal view of pedal disk.
FIG. 12. Side view of foot, showing palp-appendage and branchia.

The gills are most peculiar in *Solenomya*. As Pelseneer has shown, there is only one gill on each side having an upward and downward series from a central base. This line dividing the upper and lower series runs from the dorsal anterior portion of the gills to nearly a ventral point posteriorly (Fig. 12). The filaments are distinctly separate and are beautiful in their regularity. The filaments are arranged on the support from which they spring directly opposite each other. Each filament is supported by a chitinous rod in one series, slightly bent at the end—firm yet elastic. The same chitinous framework is seen in the gills of *Nucula proxima* and *Yoldia limatula*, as shown by Mitsukuri, Drew and others. Mitsukuri,[7] in describing the chitinous framework supporting the gills in *Nucula proxima*, says: "Whether it is really formed of chitin I do not know, but as previous writers have described the substance as of that nature it will be convenient to use the term 'chitinous support' for the present." The gills are colored a light brownish purple, their posterior terminations are free and lighter colored (Fig. 13).

A view of the posterior end of the animal reveals a single long siphonal opening which often changes its outline, at times being an oblong, oval slit, but usually the upper part, corresponding to the anal opening, is much larger, giving the aperture a double-gourd-shaped form, the upper bulb being larger. Above the anal region, just where the two shells meet, is an unpaired tubercle, or tentacle which is contractile. Stempell figures a similar

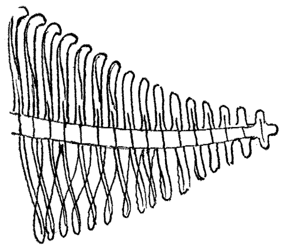

FIG. 13. Termination of branchia.

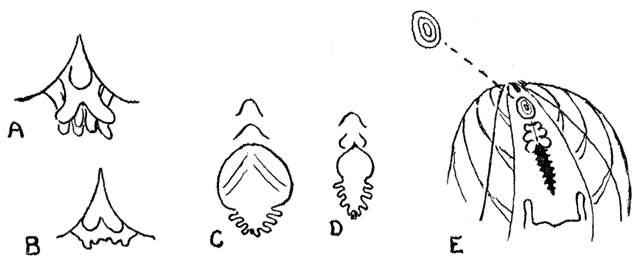

FIG. 14. Siphonal opening: *A*, *B*, from above; *C*, *D*, from behind; *E*, from behind at an angle.

tubercle in *S. togata*, and in another form to be described later a very long tentacle is seen. Just below this tentacle a pair of blunt tubercles arise which are very contractile and appear at times as two and even three pairs of tubercles. The sides of the anal opening are without tubercles. The narrow branchial opening is bordered on each side by from six to eight short tubercles or papillæ hardly varying in size. These are also contractile. A few attitudes of the siphonal opening are shown in Fig. 14.

A view of the siphonal opening from the side shows no protrusion as in the siphonal expansion of siphonated lamellibranchs. Indeed there is no appearance of a siphon, simply an

opening with papillæ about it and these quite unlike the long pointed papillæ of the siphonated lamellibranchs or even the truncate papillæ of *Saxicava*, though morphologically they are the same. On viewing this region from above the papillæ appear bunched together or spread apart, the result of the sudden dilatation or partial contraction of the opening.

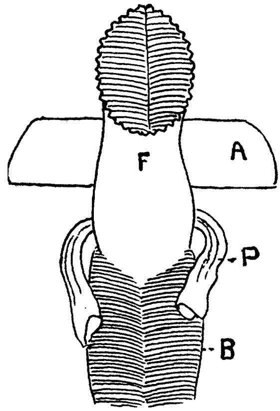

FIG. 15. Anterior end from below: *A*, anterior adductor muscle; *B*, branchia; *F*, foot; *P*, palp-appendages resting on branchia.

The sides of the siphonal opening are in constant motion in and out, though this motion is alternate and rhythmic. The proboscidiform foot swings from one side to the other within the shell, like an elephant's trunk and this motion may be related to the alternate siphonal movements; this correlation, however, was not observed.

Just below the siphonal opening a slight depression is seen on the mantle on each side connected by a transverse depression forming a symmetrical figure. Stempell shows a marking of the same nature in *S. togata* in the form of an angle with the apex downward.

A view of the animal as it rests in the usual position on its back with valves widely apart will reveal the attitude and behavior of the palpi (Fig. 15). Cutting the ventral membrane will give a clearer view of these parts. The palpi are adherent for a short distance to the side of the foot but are free beyond, and extend backward and downward. These organs are long, slender, semi-tubular with ends much larger and the whole structure delicate and diaphanous. No line or angularity in section indicates in any way that this semi-tubular appendage has come about by the adhesion of two palpi. The palpi of other lamellibranchs are more or less triangular in shape with their upper edges partly united. In *Solenomya velum*, the long tube-like appendages encircle the base of the foot with their dilated extremities resting directly on the compact sides of the

gill plates, and in this position are in gentle and constant motion with occasional side jerks. After watching these browsing movements for awhile one becomes convinced that the behavior of the ends of the palpi is that of feeding. Even the peculiar jerks at times suggest that some larger morsel has been caught. The protean shapes the appendage assumes are shown in Fig. 16. The strong ciliary action of the gills is continually sweeping along particles of organic matter toward the feeding appendages which gather the stuff and convey it by ciliary action to the mouth. The movements of these appendages may be distinctly seen through the ventral membrane and at no time are they at rest. The continual ingestion of food is indicated by the great quantity of excreta which is voided. In this connection it is interesting to note that Drew[6] in his memoir on the life habits of *Yoldia limatula*, another member of the Protobranchia, describes long appendages to the palpi which extend backward beyond the posterior end of the shell and rest on the sand. These appendages are semi-tubular and being ciliated "rapidly elevate the mud which is full of living organisms and finally pass it between the palpi," and thence, of course, to the mouth.

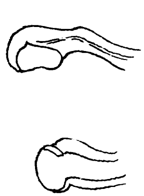

FIG. 16. Ends of palp appendages.

Mitsukuri, having described the palpi in *Nucula proxima*, says: "At their posterior end there are two remarkable structures. One of these is a hood-like structure which is the posterior prolongation of the united upper edges of the inner and outer palpi. The other, lying immediately below the first, is a long tentacular appendage. It is a hollow tube, open, however, along a line on its posterior aspect, and having its cavity continuous with the space between the two palpi. As it has been seen protruded with the foot outside of the shell, and since, in alcoholic specimens, a great deal of dirt and sand is found along its length and between the palpi from its base to the mouth, it is no doubt a food-procuring organ, probably sending a constant stream of nutritive matter to the mouth by means of its cilia. It is interesting to notice in connection with this appendage that in *Nucula*, the gills, unlike those of ordinary lamellibranchs, must be practically useless for obtaining food, as will be evident

from the following description of them," etc. Drew[4] finds these palp-appendages in *Nucula delphinodonta* functioning as food collectors. The creature is immersed in mud out of sight and only when placed in shallow mud was he able to observe its behavior. The gills are certainly very small in *Nucula*. In *Solenomya*, however, the gills are very bulky, filling nearly half the mantle cavity, are highly ciliated and as we have seen the palp-appendages rest directly on their anterior surfaces. There can be no question that these appendages in *Solenomya* are strictly homologous with the palp-appendages in *Yoldia*, *Nucula* and allies. The gills, however, are the food accumulators from which as we have seen the palp-appendages, collect the material for nutrition. The mouth is difficult to make out in the living creature. In two instances I have observed a slightly brownish line marking the position of the mouth.

While there are many features in common between *Solenomya* and the other members of the order Nuculidæ as seen in the posterior position of the umbones, the primitive gills, the palp-appendages, the fimbriated disk-like foot, the highly polished periosteum; the absence of true palpi in *Solenomya* might be considered an evidence that this peculiar form stands lowest in the order Protobranchia.

Some years ago Miss Newell discovered at Annisquam a colony of what was supposed to be *Solenomya velum*. A few were brought home alive, but circumstances were not favorable at the time for detailed study and only a few drawings were made. The shell is apparently identical with that of *S. velum* herein described, yet the character of the siphonal opening or rather the appendages surrounding that aperture are widely different. The single siphonal orifice is ano-branchial as in the other species of *Solenomya*. Above this orifice is a very long unpaired tentacle with broad base. On each side of the anal region is a broad flap bearing five tentacles, the lowest one small, the next one long slightly curved upward with three minor twigs springing from its side, the next three smaller and diminishing in size. Below this process is a wider flap supporting nine tentacles of nearly uniform length. Between the anal and branchial processes viewed from the side is a white band! I hesitate giving these

details for fear some systematist will instantly announce a new genus or family. Nevertheless, no figure nor description of *Solenomya* yet published has shown anything approaching these remarkable processes. The unpaired dorsal tentacle is short in *S. togata* (Fig. 18), even shorter in *S. velum* (Fig. 19), while in this form (Fig. 17) it is exceedingly large with a broad base. The

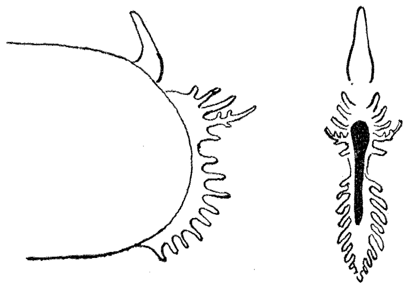

FIG. 17. *Solenomya* sp.? Annisquam.

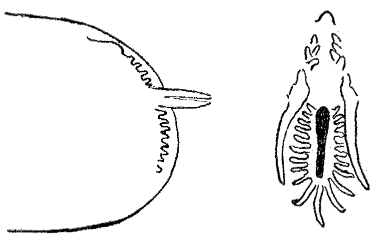

FIG. 18. *Solenomya togata.*

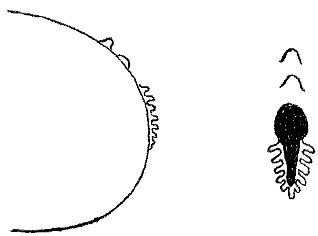

FIG. 19. *Solenomya velum.*

pedal opening shows the same tentacles starting from the posterior end of the opening. The same alternate movements of the siphonal opening were observed. The shell as before remarked differed in no respect from that of *S. velum*, and I am puzzled at the remarkable difference in structure of the siphonal opening. The question arises whether the Annisquam form may not be the young of *S. borealis*. This can only be decided by securing a living specimen of this rare form.

Professor Drew,[5] in his observations on the habits, anatomy and embryology of members of the Protobranchia, alludes to the great diversity in structure and concludes that the protobranchia have been derived from a primitive type. The resemblance he finds in certain stages of the embryo of *Yoldia* and

Nucula to those of certain other mollusks is interesting in the fact that these mollusks are in every case low and aberrant forms. He says: "The most striking peculiarities in the development are connected with the formation and disappearance of the tests. Outside of the group, so far as I have been able to learn, *Dondersia* is the only other mollusk whose embryos are known to be provided with similar tests."

Dondersia is now regarded as belonging to the Amphineura, but for awhile was looked upon as related to the worms. Drew remarks that the young embryos of *Dentalium* bear certain resemblances to the embryos of *Dondersia*, *Yoldia* and *Nucula*. Here again a resemblance is seen to an aberrant group of mollusks whose affinities were for a long time obscure. Drew also says that a somewhat similar resemblance is noticeable in the case of the embryo of *Patella*. Again a resemblance is found to a group whose characters are archaic. Dall, in speaking of the Docoglossa, says the various forms manifest what may be termed a peculiar persistency of immaturity when compared with other groups of gasteropods. Korschelt, Patten, Fisher, Lankaster, Pelseneer and others testify to the primitive characters of *Patella*. In my paper on "An Early Stage of *Acmœa*," I have collected a number of extracts from the above authors in regard to these low characters.

Pelseneer agrees with Stempell that the characteristic features of *Solenomya* represent the oldest living group of the lamellibranchs. He calls attention to the absence of a protractor pedis, extensive overgrowth of ventral mantle edges, peculiar development of the branchi-anal siphon, the form of shell and absence of interlocking teeth, with position of ligament, remarkable overlapping of periosteum, prismatic structure of limy shell, rudimentary form of mouth lips and mouth appendages, almost without winding of intestines, excessive elongation of the ventricle, the presence of pericardial glands, position, size and structure of gills, separation of kidneys without cross communication.

Interesting features will doubtless be revealed when the embryology of *Solenomya* shall have been made known, and with the abundance of one species on our coast, *S. velum*, we hope before long light may be thrown on the subject.

Appendix—Notes on Living *Solenomya borealis*.

Since the above observations were made on *Solenomya velum*, and the matter in type, the opportunity has been given me of studying living specimens of the large species *Solenomya borealis*. My friend, Major John M. Gould, collected a number of living specimens of various sizes from a young one, measuring 9 mm., to full-grown individuals, measuring 83 mm. These were obtained from dredgings in six to seven fathoms of water by a huge dredging machine engaged in deepening a channel in Portland harbor, Maine. The work of collecting, as may be imagined, was done under desperate conditions. Jumping in between avalanches of mud and water, glancing, raking and jumping out again! In this rapid reconnaisance Mr. Gould observed that the creatures were buried in holes and got the impression that they were buried posterior end downward, the broad, light-colored disk-shaped foot projecting from the holes. This attitude, as before remarked with regard to *S. velum*, is contrary to the behavior of all lamellibranches that bury themselves wholly or partially. I am still in doubt about the matter. It is interesting to note, however, that when the creature was placed on coarse material it behaved in precisely the same way as *S. velum*. In every case resting on its back it thrust out its foot, raised the anterior end of the body as if endeavoring to thrust the posterior end into the mud. In this connection, it is interesting to observe that the anterior ends of the shells of older specimens were covered with films of slime while the posterior ends were clean and polished.

In only one instance has the animal been seen to swim or dart through the water though both young and old were specially observed for this behavior. The foot was often thrust out as in *S. velum*, but not so often nor with such energy. No lateral swing of the foot was observed. The periosteum appeared oily as in *S. velum* and repelled the water, and Dr. Drew informed me that this feature was so marked in *S. velum* that when he dug them from the mud they sometimes floated on the water.

The character of the siphonal end upon which marked specific differences will be established was quite different from *S. velum* and it can now be positively stated that *S. velum* and *S. borealis*

are distinct species. It is surprising, however, to see how closely they resemble one another (Fig. 20). At first sight *S. borealis* seemed to be an enlarged *S. velum*. The color of the foot and ventral membrane varies. In *S. borealis* the foot is a light brown with a tinge of purple, darker on the ventral keel, with a darker blotch near the ventral portion. The papillæ on the edge of the

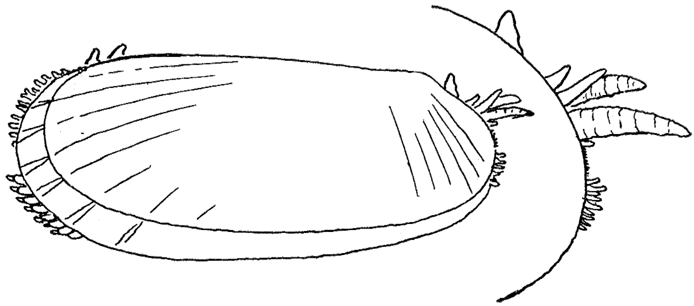

FIG. 20. Side view of *S. borealis*, natural size.

pedal disk were longer and sharper than in *S. velum* though the same in number. The tubercles on the edge of the mantle opening were the same in number and position, standing out at right angles from the ventral membrane. Their color, like the membrane, was brownish, the tips of the tubercles being dark brown. No trace of a white pigment-like color on ventral membrane

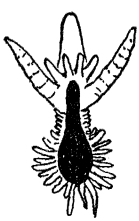

FIG. 21.

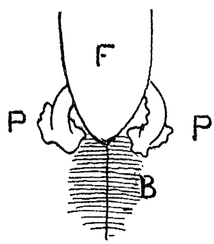

FIG. 22.

FIG. 21. Siphonal opening.

FIG. 22. Anterior end from below: *F*, foot; *P*, palp-appendages resting on the branchia; *B*, branchia.

or tubercles was observed in either young or old. The palpi were not so long though the ends were more foliated (Fig. 22). Their movements were not so active. The palpi rested on the anterior portion of the gills and were evidently engaged in secur-

ing food as described in *S. velum*. Alternate movements of the side of the siphonal opening were observed as in *S. velum*. The anterior aspect of the creature was much the same, the two median dorsal tubercles, one behind the other, and the anterior edge of the mantle bearing papillæ. The posterior aspect was quite different from *S. velum* and resembled more closely *S. togata* of the Mediterranean as figured by Stempell. The resemblances are seen in the large size of the median dorsal tubercle, the few small tentacles in pairs, succeeded by a pair of very long tentacles, then a number of very minute tentacles bordering the upper edges of the siphonal opening followed by a number of tentacles increasing in size to the lower portion of the opening (Fig. 21). All of these tentacles were retractile, the upper series appearing like round tubercles when contracted. The longer tentacles surrounding the orifice were in constant action, a bending-in movement as if grasping.

In the collection of fifteen specimens of *S. borealis* the individuals varied in length from 9 mm. to 83 mm. Omitting the smallest specimen the others were easily arranged in four distinct series of sizes as follows:

1st Series.	2d Series.	3d Series.	Full Grown.
24 mm.	39	57	73
29 mm.	40	59	77
31 mm.	44		77
31 mm.			78
			83

Twenty-eight specimens of *S. velum* from Sandwich were in the same way readily grouped in series. One measured 7 mm. in length, 6 averaged 10 mm., 8 averaged 12 mm., 5 averaged 13 mm., 6 averaged 15 mm. and 3 averaged 19 mm. From this one might infer that *Solenomya* is not an annual.

In conclusion I wish to say that this brief examination of the external features of *S. borealis* has convinced me that my supposition that the Annisquam individual might be the young of *S. borealis* is incorrect. Furthermore that a study of a more advanced specimen of *S. velum* at Woods Hole showed a nearer approach to the Annisquam specimen. I have never seen a minute specimen of *S. velum* and Professor Drew informs me that he has never found one with eggs. The protoconch of *Solenomya*

will show interesting features and the embryology of this low form will be of great importance.

EXPLANATION OF FIGURES.

Note.—Only the largest specimens averaging 19 mm. were studied. The various degrees of magnification of the figures here given may be understood in a general way by realizing that the entire length of the animal was 19 mm.

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